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Identifying Renewal Priority of Aging Neighborhoods: A GIS-MCDA-AHP Approach in the Bronx

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Abstract. Many cities today are experiencing problems of old neighborhoods and unequal access to public services. Addressing the issue of urban regeneration has become a key factor. This study aims to identify the priority areas for urban regeneration using a GIS-based MCDA method. A number of factors, including accessibility of public services, have been selected and standardized. The Analytic Hierarchy Process (AHP) method has been employed to assign weights to each factor. Finally, a weighted overlay method has been used to combine all the factors, and a regeneration priority map has been created. The results have been classified into four levels: low, medium, high, and very high priority. The areas with high priority are located in old neighborhoods with poor accessibility. The results have also been compared with the Alternative Enforcement Program (AEP) data, which shows a certain degree of coincidence. The study shows that the GIS MCDA method can be an important tool for improving the issue of urban regeneration, although there are still some limitations.

Keywords: GIS-MCDA, AHP, Urban Renewal, The Bronx.

1. Introduction

In many cities, neighborhoods built in the early stages of urban development have gradually become outdated. Residents in these areas often face unequal access to basic public services, while old housing conditions may also increase the urgency of renewal. Under the idea of inclusive growth, improving living conditions and service accessibility in disadvantaged neighborhoods has become an important planning issue [1].

Recent studies have shown that spatial decision-support methods can help planners identify areas with greater renewal needs. Among them, the combination of geographical information system (GIS), multi-criteria decision analysis (MCDA), and the analytic hierarchy process (AHP) has been widely used in urban planning and land evaluation [2]. However, many existing studies focus on city-scale or regional-scale suitability analysis, while neighborhood-scale research on aging community renewal is still relatively limited [3-6].

Therefore, this study aims to build a simple GIS-MCDA model with AHP weighting to identify the renewal priority of aging neighborhoods in the Bronx, New York City. The study generates a regeneration priority map based on housing vulnerability, service accessibility, and social impact.

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Then, the result is compared with the Alternative Enforcement Program (AEP) data to test whether the model can reasonably reflect urgent renewal needs.

2. Literature review

2.1. GIS, MCDA, and AHP in urban regeneration research

MCDA is a decision-making support tool that can handle multiple criteria with different weights to assess alternatives [7]. It is useful for studying urban problems because most urban problems are affected by multiple factors. Physical, social, environmental, and economic factors should all be taken into consideration. GIS is another decision-support tool regarded as useful for studying urban problems. This is because of its capability to store, sort, analyze, and visualize spatial data [8]. Nevertheless, the application of both MCDA and GIS has been regarded as useful in addressing urban problems, particularly in pinpointing areas.

AHP is another useful decision-making tool for assigning weights to the criteria. It was developed by Saaty, as shown in [9]. It has been seen as helpful for assigning weights to the criteria, as it allows the researcher to make comparisons between the criteria. It is useful because it provides a structured way to make decisions.

Various researchers have already used this approach in other aspects of planning studies. Meng et al. As an example, this approach was used to study housing location accessibility in Canmore, Canada [3]. Huang made use of this approach to evaluate the urban regeneration potential in London with AHP and entropy weight methods [4]. A similar approach was adopted by Abdelkarim et al. In the work of evaluating relocation sites for slum upgrading in Cairo [5]. Some studies made use of this approach for the planning and expansion of urban green spaces [6].

While it's shown by these studies that this approach can be used to evaluate different aspects in urban planning, most of them used it on a larger scale, like the whole city or region. There are still a small number of studies using this approach to evaluate aspects on a smaller scale, for example, in urban regeneration. A number of studies started looking into this approach in old communities. Like the Seoul study, it used this approach to reveal different problems in accessibility, walkability, and vulnerability [1]. Nevertheless, this study mainly centered on public service allocation and failed to create an easy-to-use framework for identifying old-neighborhood regeneration potential.

2.2. Analytical framework of this study

Based on previous studies, this research uses a combined GIS-MCDA-AHP framework to identify renewal priority in the Bronx. The process includes data collection, indicator selection, standardization, AHP weighting, GIS weighted overlay, and model validation.

Three dimensions are used in the model: Housing Vulnerability, Service Accessibility, and Social Impact. These dimensions are represented by six indicators in total. After all indicators are standardized into comparable scores, AHP is used to determine their relative importance. Then, a weighted overlay method in GIS is applied to generate the regeneration priority index (RPI). Finally, the result is validated by comparing high-priority areas with the AEP dataset.

3. Study area and data

The Bronx was selected as the study area because it is highly relevant to the topic of aging neighborhood renewal. It is one of the five boroughs in New York City and has serious housing and socio-economic challenges. The borough has a large population, a high poverty level, and many old

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residential buildings. In addition, housing violations in the Bronx have remained severe for a long time. Because of these conditions, the Bronx is a representative case for studying renewal priority in aging urban neighborhoods [10-12].

The main data sources used in this research come from NYC Open Data. Two significant data sources come from PLUTO and Housing Maintenance Code Violations. PLUTO contains data such as land use, building age, and the number of units in the building. This data helps to identify the physical conditions of the building [13]. Housing Maintenance Code Violations, especially Class C, help to identify serious hazards in housing conditions [12]. Other data sources come from subway-related data, healthcare facilities, and parks [14,15]. They become spatial indicators in the next analysis.

4. Methods

4.1. Indicator selection

According to the Bronx's local conditions and previous GIS-MCDA studies, six indicators were selected under three dimensions [1,3-6].

The first dimension is Housing Vulnerability, including year built and Class C violations. Building age is used because old housing is more likely to have outdated infrastructure and higher physical risk. Class C violations represent immediately hazardous conditions, such as water shutoffs or electricity outages, and therefore directly reflect housing distress [12].

The second dimension is Service Accessibility, including distance to subway stations, healthcare facilities, and parks. Subway accessibility is important because public transportation is a major part of daily travel in New York City. Healthcare facilities are essential daily services, while parks are related to exercise, social activity, and general well-being [16].

The third dimension is Social Impact, represented by the number of units. The logic is that renewal of a larger residential building may affect more residents than renewal of a small one. Therefore, a larger number of units means a larger possible social benefit from intervention.

4.2. Indicator standardization

Table 1. Indicator standardization criteria

Dimension	Indicator(Field)	Score1 (Low risk)	Score 2	Score 3	Score 4	Score 5
Physical deterioration (weight 65%)	Building age	After 2000	1970–1999	1946–1969	1920–1945	Before 1920
	Severe violations	0	1–5	6–10	11–20	>20
Service accessibility (weight 23%)	distance to subway	<1000 ft	1000–2000 ft	2000–3500 ft	3500–5000 ft	>5000 ft
	Distance to healthcare	<800 ft	800–1600 ft	1600–3000 ft	3000–4500 ft	>4500 ft
	Distance to park	<500 ft	500–1000 ft	1000–2000 ft	2000–3000 ft	>3000 ft
Social impact	Residents units	1–5	6–20	21–50	51–100	>100

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Because the selected indicators have different units and meanings, they must be standardized before overlay analysis. In this study, each indicator was divided into five scores, from 1 to 5, as summarized in Table 1. A higher score means a higher renewal priority in the final model.

The classification refers to both related studies and the actual situation of the Bronx. For accessibility indicators, the scoring mainly follows walking distance and general assumptions of acceptable access to daily services. This step makes all indicators comparable and suitable for later weighting and overlay.

4.3. Weight determination by AHP

This study uses AHP to calculate the relative importance of each dimension and indicator. The process includes hierarchy construction, pairwise comparison, and consistency check [9]. First, the three major dimensions were compared with each other. In this study, Housing Vulnerability was considered more important than Service Accessibility and Social Impact because the research mainly focuses on aging neighborhoods and urgent housing conditions. As a result, Housing Vulnerability received 65% of the total weight.

Then, indicators within each dimension were compared. A 3×3 matrix was used for the three service accessibility indicators, while a 2×2 matrix was used for the two housing vulnerability indicators. After the pairwise comparisons, consistency ratios were checked. All CR values were below 10%, which means the weighting result is acceptable.

4.4. Weighted overlay and model validation

After standardization and weighting, the final regeneration priority index was calculated by the formula:

$$\mathrm{RPI} = \sum (\mathrm{w_i} \bullet \mathrm{x_i}) \tag{1}$$

where wi is the weight of each criterion, and xi is the standardized score.

A weighted overlay method in GIS was then used to combine all indicator layers. Each layer was given a weight and then added together to make the final regeneration priority map.

The final map was divided into four levels: low, medium, high, and very high priority. Although the original indicators were scored from 1 to 5, the weighted results in this study only fell between 1 and 4, so the final map was grouped into four levels.

To validate the model, the AEP dataset was overlaid with the high-priority areas. AEP is a housing enforcement program that identifies the most distressed residential buildings with severe violations [17]. If AEP buildings are largely located in high-priority areas, the model can be considered reasonably effective. However, since AEP mainly reflects housing distress, this validation is only an external reference rather than a complete proof of the whole model.

5. Results and discussion

The GIS-MCDA model produced a regeneration priority map of the Bronx, as shown in Figure 1 (a). Based on the weighted overlay result, the RPI was classified into four levels: low, medium, high, and very high priority. The spatial distribution shows a clear pattern. High and very high priority areas are mainly concentrated in several clusters, while low-priority areas are more scattered. This suggests that renewal demand in the Bronx is not evenly distributed, but spatially aggregated.

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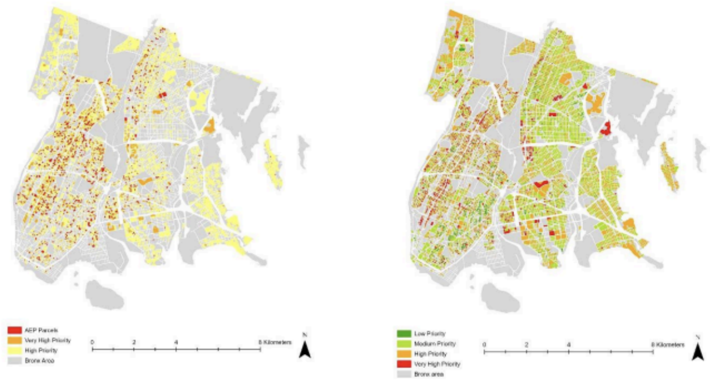
Most areas fall into the medium-priority level, while high and very high priority areas occupy a smaller proportion. This pattern is also common in other GIS-MCDA studies, where the most critical areas are limited in space but important for intervention [4-6]. In this study, high-priority areas are generally related to older buildings, higher numbers of Class C violations, and poorer accessibility to daily services. This means that both housing conditions and service accessibility are important in shaping renewal demand.



(a) Renewal Priority Map Generated Using the GIS-MCDA Model

(b) Spatial validation of the GIS-MCDA Model Using AEP Parcels

Figure 1. Results of GIS-MCDA methods

Picture credit: Original

To check the validity, Figure 1 (b) shows the AEP dataset that has been contrasted with the model results. There are 1,043 buildings in AEP. Out of them, 1,041 are in areas with a non-zero RPI value, and 930 are in areas with an RPI value of at least 3. It shows that there exists a strong-ish overlap between the model results and the actual data for distressed housing.

There are also high-priority areas identified by the model that are not included in the AEP dataset. It could be an indication that the model not only pinpoints distressed housing but also has the ability to find areas with possible problems yet to be in the programs.

There are some limitations associated with the AHP method as well. The first thing may be related to the way we classify the indicators, with some degree of subjectivity. The AHP method depends on some subjective judgments, which implies that the final outcome may vary according to the researcher's experience and preference. The validation of the results may not address all potential problems as only one dataset was employed. Another factor associated with the weighted overlay method can affect the calculation results to some extent. The difficulty is that there is a full-fledged trade-off among the different indicators. One can scarcely deny that there's a chance a high score could offset a low score. It's possible that not all problems can be compensated. Some emerging housing-hazard problems may need immediate attention, even with relatively good park access. Additionally, using the AHP method to assign weights can also cause some subjective impacts.

In spite of its weaknesses, the study has a certain value as a simple framework for establishing renewal priority in the neighborhood. In comparison to other studies, this method may have greater sensitivity to neighborhood variations, useful for setting renewal priority.

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6. Conclusion

This study attempted to explore a simple approach for evaluating the renewal priority of old building areas and neighborhoods using GIS-MCDA with AHP. The study area for this research is The Bronx, which faces a typical series of economic and housing challenges.

The regeneration priority index (RPI) map has been created using a series of factors, including housing condition, service accessibility, and social impact. The analysis indicates that high-priority areas are not evenly distributed but are rather concentrated in clusters. The areas that are highlighted as high priority are mostly associated with old buildings, housing violations, and poor accessibility to public services. The validation analysis indicates that there is a relatively high overlap between the model output and the AEP dataset.

On the map, there are some areas that are highlighted as high priority but do not coincide with the AEP data. This may indicate that the model is capable of identifying potential problem areas that are not yet included in the AEP.

Some limitations are associated with this study. Firstly, there is a degree of subjectivity associated with the selection of the factors and the classification of the factors. Secondly, there is a degree of subjectivity associated with the AHP method as well.

This study has demonstrated that the GIS-MCDA with the AHP method is capable of being a useful tool for urban regeneration analysis at the neighborhood level. Overall, the model shows good potential for identifying areas with high renewal priority and can be adapted for other studies with spatial analysis needs. Choosing different indicators and weights can highly influence calculation results. And this showed a potential for adjusting and customization.

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